STEEL SLAG HANDLING SYSTEM

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This application is a continuation-in-part of my co-pending applications Ser. No. 126,792 and Ser. No. 304,932, filed June 28, 1961 and Aug. 27, 1963, respectively, both now abandoned.

The present invention relates to a system for more efficient, faster and more economical removal of slag discharged from steel-making furnaces, and recovery of ferrous material therefore. More especially, the present invention relates to a new improved method and apparatus for converting red-hot slag discharged from an open-hearth furnace into a granular mixture of ferrous and slag particles of relatively small size and low temperature, and rapidly conveying the resultant granular mixture from the furnace building during the steel-making operation, with related means for transporting said granular mixture to and through a magnetic separator to reclaim the usable ferrous material and suitably dispose of non-ferrous slag.

For some years, steel in large quantities has most commonly been made in "open hearth furnaces," in which ingredients such as scrap iron, pig iron, hot molten iron from blast furnaces, ore, limestone, etc., are melted and refined to produce molten steel. A substantial quantity of slag is formed over the molten steel bath in the open hearth furnace and plays an important part in the steel-making process. Typically, the slag constitutes about one-fifth of the total charge to the furnace in a heat, hence, in a modern open hearth furnace having a capacity of 350 tons per heat, about 65 to 70 tons of slag are formed and must be disposed of within a relatively short time. Generally, a modern open hearth furnace plant contains 10 to 15 stationary furnaces of 200 to 350 ton capacity, which are substantially continuously operated on staggered heat cycles, so that a tremendous amount of slag must be removed from the furnace building each day.

Efficient quick removal of such large quantities of slag from adjacent the open hearth furnaces and out of the furnace building is a long-standing major problem in steel manufacture. This problem has been greatly accentuated since World War II by the development of modern techniques which make it possible to produce substantially greater quantities of steel per heat in a substantially shorter time with existing open hearth furnaces. Since World War II, the average per-heat capacity of open hearth furnaces has been increased from about 100 tons to about 200–350 tons; and heat time, from tap to tap, has been decreased from about 10½–11 hours to about 8–9½ hours. Increasing use of oxygen and other improved operating techniques has now made it technically possible to reduce the heat time for a 350-ton furnace to about 4 hours. It is estimated that a steel mill containing an open hearth plant with eleven furnaces of 350-ton capacity per heat, plus related plant, represents a capital investment of about one hundred million dollars ($100,000,000). Also, it is estimated that the reduction of one minute of heat time "from tap to tap" represents a saving of thirty thousand dollars ($30,000.00) per year for such an open hearth plant containing eleven furnaces. Thus, the tremendous economic significance of utilizing available techniques to operate open hearth furnaces at minimum heat time will immediately be apparent. Likewise, such operation of open hearth furnaces at minimum heat time would greatly increase the national defense capacity of the United States steel industry with existing open hearth facilities.

The need for an efficient system of removing increasingly large quantities of slag in a shorter, time, at reasonable cost, is thus a matter of serious concern to the steel industry.

For a long time, and until just a few years ago, it was common practice in leading mills to discharge open hearth slag into cast-iron slag pots removed from the furnace room by rail cars. In this prior rail slag-pot system, when the charge to the open hearth required a slag run-off or flush during the heat (as when a high percentage of molten pig iron was added to the melt), provision was made for run-off of slag through a notch in the back wall of the open hearth furnace at one side of the tap hole, whereby early slag passed through the run-off notch into a spout and thence to a slag pot on rails behind the furnace. In addition, when the furnace was tapped at the end of the heat, the slag following the molten steel into the steel ladle would overflow from the top of the ladle into an adjacent slag pot through a slag spout extending from the ladle side. Then the ladle crane lifted the slag pot to a rail car on the pit side which was later removed to the slag yard. Early slag was sometimes also removed by “front flush” from the furnace through a notch or trough cut in the refractory bank at the lower edge of the center furnace door and thence through an opening in the charging floor into another slag pot set on a rail car at the yard level in the open hearth building. These slag pots were then removed by a locomotive from the open hearth furnace building to a suitable disposal area where the slag was dumped, and then were returned to their aforementioned positions adjacent the furnace.

However, this rail slag-pot system proved inadequate and unsatisfactory for removal of greater tonnage of slag in less time, as open hearth furnace capacity increased and melt time decreased. Consequently, leading steel plants have adopted a system in which part of the slag is "front flushed" from the center furnace door under the furnace to the pit side, and the remainder of the slag is flushed from the steel ladle to the pit floor when the furnace is tapped. Thereafter, "highlift" tractors and heavy-duty trucks are used to remove the slag from the pit side of the open hearth furnace building when the steel ladle is removed after pouring the heat. (This current system is illustrated in FIGURES I–3 of my earlier application, Ser. No. 126,792.) With a heat time of about 8 to 8½ hours for a 350-ton furnace, about 60 to 70 tons of hot slag must be removed from below and behind the furnace, loaded, trucked to a disposal point, unloaded, etc., in about 1 to 1½ hours. If the slag is not removed from beneath the open hearth furnace in this short time, while the open hearth furnace is being re-charged, as sometimes occurs, remaining slag under the furnace must be left there until after the next heat is completed. By then, this slag has solidified and becomes very difficult to remove; moreover, the newly formed slag from the next heat must also be removed in the limited time available while the furnace is again re-charged. In some mills, a costly heavy-duty tractor with a special stripper attachment is maintained on a stand-by basis to strip solidified slag from the furnace pit, so that it can be loaded on trucks by the "highlift" tractors. Even though this special stripper equipment may be idle 85% of the time, it is deemed warranted to prevent much more costly loss of furnace operating time due to inadequate slag-removal operations. Furthermore, this slag removal operation is very rough on the equipment used, so that there are serious and continuous maintenance problems which potentially can cause a loss in furnace operating time, besides...
requiring substantial maintenance facilities and reserve equipment.

The need for round-the-clock removal of high tonnages of slag has led to use in one of the most modern United States open hearth shops of a "tractor wagon" capable of hauling 30 tons of hot slag, loaded by highlift tractors. This, however, involves an approach to problems similar to those involved with the aforementioned highlift and truck system for handling slag (more fully discussed in my aforementioned parent application Ser. No. 126,792 with reference to FIGURES 1–3 thereof).

It has been apparent for some time that this currently used multiple-step materials-handling system for removing open-hearth slag after tapping has serious inherent limitations, whereby it cannot be successfully utilized if the furnaces are run at the materially shorter heat times that are now feasible, and especially with four-hour heats.

The problems of handling and removing steel slag have been seriously increased by the steel industry's rapid adoption of the water and slag during the introduction of the latter into the former whereby the basic process is rendered capable of commercial application in the treatment of steel-making slags.

"It will be readily appreciated by those skilled in the art that slags produced in steel-making operations are tapped from the furnace at a considerably higher temperature than are blast furnace slags. This factor creates an unusual problem in that the higher temperature steel-making slag tends to combine explosively with the water due to the extremely rapid generation of steam and liberation of hydrogen and carbon monoxide gases. Thus, methods heretofore known to be effective in the granulation of blast furnace slags have been found to be dangerous and/or inoperative when applied to the treatment of steel-making slags."

The aforementioned Harisco Canadian patent seeks to successfully and safely granulate steel slag on a practical commercial basis by pouring the molten slag into a bath of water in a tank, with water fed into the tank below the water-bath surface and as low as one-half way to the bottom of the tank to create a water current in the bath at this level. Contrary to the objectives stated in the Canadian patent, the steel-slag system of that Harisco patent is susceptible to explosion, and is dangerous, if not inoperative, aside from otherwise being impracticable and unacceptable from the viewpoint of real-life steel mill operations, for many reasons. Reportedly, the system of the Tomlinson-Harisco Canadian patent was tried for handling molten steel slag, with resultant explosion, and was abandoned. In any event, although Harisco is one of the largest handlers of steel slags in the United States, it does not use the Canadian patent system for steel slag.

Instead, the U.S. steel industry and its slag contractors, including Harisco, continue to use such above-discussed batch-type, multistep, slag handling systems, utilizing slag pots with rail cars, vehicles or cranes, or highlifts and tractors, etc., in spite of the many shortcomings and problems of such prior systems.

Hence, removal of steel slag by multiple-step batch systems has been and is a "bottleneck" that prevents the maximum utilization of existing open hearth and OSDM and BOF furnaces, and the realization of tremendous economic savings and other advantages, which would be thus achieved.

It is therefore a primary object of this invention to provide a new improved slag-removal system which departs from the materials-handling concept of current and earlier systems, such as discussed above, by avoiding their serious shortcomings and making it possible to achieve continuous removal of the slag from the open hearth building as the slag is being discharged from the furnaces during the heat. More particularly, it is an object of the present invention to provide a new improved slag-removal method and apparatus whereby the very hot slag from the open hearth furnace is discharged to a "granulator" wherein it is suddenly cooled and granulated by jets of water or the like to form relatively small discrete particles of ferrous and slag material, which is then transported by continuous conveying means from the open hearth building. It is another related object of this invention to thus achieve complete removal of slag produced in a large heat within a very short time after the open hearth is tapped, whereby slag removal no longer constitutes a "bottleneck" preventing optimum use of oxygen and shorter heat times in large capacity open hearth furnaces and OSDM or BOF furnaces.

It is another object of the present invention to provide such a new improved slag-removal system by which the granulated slag and ferrous material can be conveyed directly to magnetic separating means for quick, efficient, and economical separation of reusable ferrous material from the non-ferrous slag.

It is another object of the present invention to thus achieve the steel mills with better control over the reclaiming of usable ferrous material from open hearth slag, thus cutting the mill's cost for such materials which are re-used in its open hearth furnaces.
It is still another object of this invention to provide such a novel improved slag granulator removal and metal recovery system which substantially reduces the high labor cost per ton of the currently used slag removal and recovery systems, and which also greatly decreases the cost of equipment per ton of slag removed compared to prior slag-removal systems. It is another related object to eliminate the serious and costly equipment maintenance problems encountered with the currently used slag-removal system, through resort to my new slag-granulating-and-particle-conveying system.

It is yet another object of the present invention to increase the safety of slag-removal operations, thus furthering the diligent efforts of U.S. steel companies to continuously improve safe working conditions in the mills, which is a matter of prime concern to the U.S. steel industry.

It is another related object of this invention to provide a water jet granulator which has a novel arrangement and mode of operation whereby it is capable of handling large tonnages of molten steel slag in a short time period, without creating explosions, or other dangerous or otherwise undesirable working conditions which the steel industry has heretofore encountered in attempting to granulate steel slag with water.

It is another object of the present invention to provide such an improved slag-removal system incorporating means for diverting the front-flush slag from the granulator to the pit below the open hearth furnace, for removal in conventional manner in the event that should prove necessary or desirable. It is a related object to provide a novel movable slag discharge runner or spout arrangement for the slag granulator, which chute is removable from below the front flush spillway to permit this alternate handling of the slag.

It is yet another object of this invention to provide various alternate systems for handling steel ladle overflow slag, including a method and apparatus whereby the ladle slag is granulated in the same granulator as the front-flush slag, in the "kitchen" of the open hearth furnace building, thus eliminating slag-removal equipment from the pit floor and pouring side of the building. It is a related object to provide such systems in which ladle slag can also be diverted from the granulator to the pit floor, if desired.

It is another object of this invention to provide such a novel improved water jet slag-granulating-and-handling system which safely and rapidly processes large tonnages of molten steel slag and therefore can be used for handling OSM and BOF steel furnace slags; for rapid processing and disposal of large tonnages of such steel slag in minimum time, thus meeting various objectives and advantages more particularly discussed herein with reference to handling large tonnages of open hearth steel slag.

Other important objects and advantages of the present invention will be apparent from the following description thereof with reference to the accompanying drawings, and from the claims appended hereto.

In the drawings:

FIGURE 1 is a perspective diagrammatic illustration of the overall slag-removal system of the present invention;

FIGURE 2 is a diagrammatic cross-section of an open hearth furnace (along a line through the tap spout) showing one embodiment of the slag-removal system of this invention, including a granulator for converting hot slag front flush through the center open hearth door and also the steel ladle slag;

FIGURE 3 is an enlarged side elevation view of the slag granulator with steam removal and other related apparatus shown in the lower right portion of FIGURE 2 (some parts being broken away for greater clarity);

FIGURE 4 is a top plan view of the slag granulator and related apparatus shown in FIGURE 3 (some parts being broken away for clarity);

FIGURE 5 is an enlarged top plan view of the water jet nozzles used in the slag granulator shown in FIGURES 3 and 4 (portions thereof being broken away for clarity);

FIGURE 6 is an elevation view of the slag granulator nozzle shown in FIGURE 5 (looking to the left at the nozzle in FIGURE 5);

FIGURE 7 is a side elevation view of the granulator nozzle shown in FIGURES 5 and 6 (a portion being broken away for a clearer showing);

FIGURE 8 is a schematic perspective showing of the conveyor, magnetic pulley and "splitter" arrangement for separating magnetic ferrous particles from non-ferrous particles in the granulated slag mixture which is conveyed from the granulator of FIGURES 2 and 3;

FIGURE 9 is a diagrammatic cross-section of an open hearth furnace (along a line through the center charging door, and similar to FIGURE 2), showing in greater detail the movable-chute arrangement for the slag granulator in the "kitchen," whereby the chute which conveys the front-flush slag to the granulator can be removed from below the front-flush spillway extending through the charging floor so that the front-flush slag is diverted to the slag grade hill below the furnace;

FIGURE 10 is an enlarged perspective view of a preferred chute for conveying front-flush slag to the granulator in the kitchen as illustrated in FIGURE 9;

FIGURE 11 is a diagrammatic top plan view illustrating a modification of part of my improved slag-removal system shown in FIGURE 4, in that another granulator and conveyor system, etc. (per FIGURES 3–7) is provided on the pit side of the open hearth for granulating slag discharged from the steel ladles and then removing the same from the open hearth furnace building, the granulator tank being mounted on a rail car in the pit side so that it can be moved from ladle to ladle behind each of the furnaces, together with related conveyor means, etc.

FIGURE 12 is a diagrammatic cross-section of an open hearth furnace, illustrating the prior art practice of discharging front-flush slag from the charging door to below the furnace and the pit side, and the spill-off of slag from the steel ladle to the pit floor, before removal by "high-lift" tractor or truck.

In the following description, like numerals are used for like parts throughout; in some instances, where parts are modified, comparable parts are identified by like numerals and subscripts, as explained when applicable.

Referring to drawings FIGURES 1, 2, and 12, by way of background, a typical open hearth steel plant contains a plurality of open hearth furnaces 20 (usually ten to fourteen) installed in a line within the furnace building generally indicated at 22, as illustrated particularly in FIGURE 1.

In a so-called "two-level shop," the furnace building 22 contains a charging floor 24, which is usually about 22 feet above the general yard level of the building, with an area 26, called the "kitchen," below the charging floor. The remainder of the floor space of the furnace building located on the tapping side of the open hearth furnaces 20 is called the "pit side" or "pouring floor," which is indicated by numeral 28 in the drawings and is at general yard level. The charging floor 24 is laid with various tracks (not shown) for operation of rail cars and charging machines for feeding scrap and/or pig iron into the open hearth furnaces 20.

The open hearth furnaces 20 are rectangular brick structures comprising a front wall 30, a pan-type bottom 32, a back wall 34 which is usually sloping, a roof 36, and end walls 37, which are lined with suitable high-temperature refractory material. This rectangular brick structure is supported on the sides, ends, roof, and bottom by steel framing which is diagrammatically shown at 38 in the drawings. In FIGURE 2, there is schematically shown an oxygen "lance" 45, whereby oxygen is introduced into the steel bath during the steel producing proc—
ess, greatly decreasing the time per heat in modern open hearth furnace practice, as previously mentioned. Details of the open hearth furnaces 20 and related equipment within the open hearth furnace building 22 are not shown or described except to the extent helpful for full understanding of the present invention. For more details on open hearth furnaces and operation thereof, see chapter 15 of "The Making, Shaping and Treating of Steel," 7th edition, United States Steel Corporation (1957), and items in the bibliography on pages 332–333 thereof.

The front wall 30 of the open hearth furnace 20 contains a plurality of charging openings 39 (usually five or seven in number) and each of these is covered by a charging cover 40 that is vertically movable within water-cooled frames 42 by a lifting cable or the like, indicated at 44, which is usually operated by an electric door hoist. Each of charging doors 40 is provided with a peep hole 43, called a "wicket," to permit inspection of the interior of the melting chamber of the open hearth.

By tending especially now to FIGURE 2, the rear furnace wall 34 is provided with a tap hole 46 located midway between the ends of the open hearth furnace 20, with its inner end at a low point of the furnace hearth bottom 32. Tap hole 46 is adapted to communicate with a tapping spout 47 which is located above the tap hole 46 and is unplugged at the end of a melt to remove the steel from the furnace. Below the outer end of the tapping spout 47, there is disposed a steel ladle 50, which has a configuration substantially as shown in the drawings and is mounted on ladle stands 52 by means of mounting blocks 54 extending from the sides of the ladle 50 and resting on the stands 52 (as shown especially in FIGURE 12). The mounting blocks 54 on each side of the steel ladle 50 are provided with laterally extending cylindrical trunnions 56, which are engageable by the hook of an overhead crane (not shown) for removal of the steel ladle 50 after tapping of the open hearth furnace 20 to the ingot pouring platform (not shown). (See aforementioned text on steel making, especially Figure 15–1.)

The steel ladle 50 is also provided with a slag spout 88 extending laterally from the upper edge of the ladle 50, which has a portion thereof cut out to permit overflow through 88 of slag poured into the upper part of the ladle on top of the steel at the end of a furnace tap. The steel ladle 50 also is provided with a stopper rod and operating means for pouring of the steel from the ladle, schematically shown at 60 in the drawings.

FIGURE 2 shows a typical open hearth furnace and steel ladle arrangement, and illustrates slag handling according to prevailing practice in leading mills. As shown especially in FIGURE 12, during the steel-making operation, part of the slag overlying the steel bath in the furnace 20 is discharged through a notch or trough 62 cut in the refractory of the front bank of the furnace at the center door 46. This "front flush" slag 64, which is thus discharged from the front side of the furnace, passes through the opening in a hollow casting 66 set in the charging floor 24 and into a pit 68 below the furnace, which is formed by spaced walls 70 extending from the yard level to the underside of the furnace 20. The pit 68 below the furnace is filled with dirt or debris to form a hill 72, whereby the hot and viscous front-flush slag discharged through the opening in charging floor 24 pours onto this hill and flows down it towards the pit side of the furnace, as schematically shown in FIGURE 12. Some slag spills down to adjacent steel ladle stands 52, while some of it cools to such extent that it remains in the pit 68 below the furnace 20. The front flushing of slag may continue for 1–1½ hours in good operating practice with a 350-ton furnace; but, at times, slag is front flushed at a very high rate, estimated as high as four tons per minute.

At the end of the steel-making heat, when the plug in rear furnace tap hole 46 is removed, the lower layer of steel runs from the bed of the open hearth furnace 20 through tap hole 46 and tapping spout 48 into the steel ladle 50. Since the tapping hole 46 is located with its highest level at the lowest part of the furnace hearth and slopes downward to meet the tapping spout 48, the greater portion of the steel flows out of the furnace before the slag in the furnace (which has not been front flushed) is completely tapped. The furnace therefore follows the tap hole 46 and tapping spout 48 into the steel ladle 50, on the top of the molten steel. The ladle slag spout 58 is of suitable vertical dimension with respect to the ladle 50 so that most of the excess slag flowing into the ladle from the open furnace will overflow the ladle 50, leaving, however, a small amount of slag as a covering for the steel in the ladle, according to good practice. In the current slag-removal system, this ladle slag 67 is discharged to the pit floor along side the ladle stand 52, as will be apparent from FIGURE 12.

After the steel has been poured and the slag/overflow 67 has been discharged from the ladle, the tapping spout 48 is removed by a spout hoist (not shown) and the steel ladle 58 is removed from the supporting ladle stands 52 to the ingot molds at the pouring platform, by one of the pouring cranes. Then "highlift" or loaders promptly begin to remove slag from the pit floor 23 behind the furnaces, and load the slag onto heavy-duty trucks, which carry the slag from the furnace building. In order to remove the front-flush slag from the pit 68 below the furnace 20, it is necessary for the highlift truck to operate within this pit, in quite close quarters between the adjacent walls 70 below the furnace. Sometimes, in order to clear the slag from below the furnace 20 in the limited time before the furnace is recharged and ready for the next melt, the front-flush slag 64 is moved to alongside the ladle stand 52 by the tractor operation and then later loaded on trucks, since there is more room for removal of the slag which is not below the furnace proper. The "highlift" bucket can handle about 5 tons of slag, and semi-molten hot slag is loaded by the "highlift" tractors on trucks (or tractor wagons) in rather huge lumps, each of which may weigh tons.

Usually, the trucks must carry away several loads of slag for complete removal of the slag discharged from a 350-ton furnace heat. As previously mentioned, sometimes the slag cannot be removed from the pit 68 below the furnace 20 before the next heat is ready, and must be left for removal after completion of the next heat together with the new slag then discharged.

The hot slag loaded on the trucks (or tractor wagons) is transported to a so-called "skull cracker" where the large slag pieces are broken up by dropping a weight on them, whereafter the larger more readily recoverable usable ferrous material is separated from the non-ferrous slag, generally by a magnetic-crane operation. This larger usable ferrous material is ultimately returned to the open hearth furnaces for making of steel, and the remaining mixture of slag and ferrous material is generally transported to a recovery dump. Subsequently the latter slag-and-metal mixture is processed in a sizing-and-separating system for additional recovery of recoverable ferrous material, usually by breaking the slag and metal into relatively small particles and then separating ferrous material from slag, by known techniques. The additional usable ferrous material thus recovered is ultimately transported to the open hearth furnace for re-use, and the non-ferrous slag and gangue is transferred to a dump or other disposal point.

While this currently used slag-removal system is a substantial improvement over the rail slag-pot removal system previously used, it will be apparent that such slag removal by highlift tractors or tractor wagons has definite limitations. It is, therefore, proving inadequate for removal of larger tonnages of slag in shorter periods of time as the heat time of open hearth furnaces is decreased, thereby greatly decreasing the already
limited time available for the tractors to remove and load the slag, especially the front-flush slag, which represents about 65% of the total and must be removed below the furnace before the next heat is started. Also, it will be apparent that this current materials-handling system which removes the slag in huge chunks necessarily requires a multi-step process for recovery of the re-usable metal from the slag, with a considerable amount of step-by-step handling, whereby the metal re-claiming system is less efficient and more costly than desired.

Referring now to FIGURES 1-11, the new improved slag-removal-and-metal-recovery system of the present invention will now be described.

Referring especially to FIGURES 1 and 2, in this new system, the front-flush slag 64 is discharged through a short rectangular chute 66a in the charging floor 24 into an inclined trough-shaped front-flush slag runner or chute 78, which extends through an aperture 25 in vertical wall 27 and is suspended from the underside of the charging floor 24 by suitable means generally indicated at 80 in FIGURE 2 (and hereinafter amplified with reference to FIGURES 9 and 10). The front-flush slag spills from the lower end of the runner or chute 78 into one end of a granulator generally indicated at 82, which is located at yard level in the kitchen, and is fully described below.

In the embodiment illustrated in FIGURE 2, the slag spout 58 on the steel ladle 50 is disposed with its axis substantially perpendicular to the longitudinal axis of the furnace 20 and substantially in line with the center door front-flush trough 62. The quite hot and substantially viscous ladle slag 67 is discharged from the spout 58 to an inclined trough-shaped runner or chute 78, whose lowermost end overhangs the end of granulator 82 which is nearer the furnace. The lower portion of ladle slag runner 79 extends over the upper end of the slag grade or hill 72 formed by dirt or debris within the pit 65 under the furnace 20, and also extends through a suitable aperture 31 in the vertical wall 27, as illustrated in FIGURE 2. If the ladle slag chute is unitary it is movably supported by suitable means, such as chain hoists on a monorail, indicated at 83 (and hereinafter amplified).

The ladle slag runner or chute 79 can also be made in two sections, as illustrated, including an upper trough-like section 79a of smaller cross-sectional size and a lower section 79b of slightly larger cross-sectional size, whereby the lower end of upper runner section 79a may movably nest in the upper trough-shaped end of lower runner section 79b, with overlapping portions indicated at 79c in FIGURE 2. The upper ladle slag runner section 79a may be individually movably supported by suitable means, such as schematically indicated at 83 in FIGURE 2 (and hereinafter amplified), as is also the lower runner section 79b. This makes it possible to remove runner section 79a from ladle slag run-off position of FIGURE 2 to adjacent the underside of the furnace for any desired purpose, without moving the part of the ladle slag runner which extends through aperture 31 in wall 27.

It is noted that when the ladle slag is transported to a granulator in the kitchen, as in the embodiment of FIGURE 2, the wall 27 can be made as a short retaining wall extending from yard level only the distance between the furnace 20 and the granulator necessary to support the slag grade 72, thus providing greater access to, and more room for movement of, ladle slag runner 79 (or 79b).

Ladle slag discharge chute 79, or a two-part chute 79a and 79b, may be made in any suitable manner and of suitable material (e.g., cast steel which may be lined with refractory), in a manner which will be apparent to those skilled in the art in light of the disclosure herein. (Hence, more detailed disclosure of the chute per se contained herein is deemed unnecessary.)

Referring especially now to FIGURES 3-7, the slag granulator 82 comprises a large rectangular tank which is somewhat boat-shaped, as is especially apparent from FIGURES 3 and 4. In the illustrated embodiment, the granulator tank 82 includes a framework comprising: a pair of angles 84 along the bottom longitudinal edges on opposite sides of the tank; a pair of angles 90 forming the long sloping upper edges on opposite sides of the tank; and a plurality of angles 96, 98, 100 and 104 extending between bottom sides angles 84 and top side angles 90, on both sides of the tank (as is especially apparent from FIGURE 3) to form supporting framing for the longer tank sides. The tank of granulator 82 also comprises: a horizontally disposed rectangular bottom plate 106; a sloping bottom rectangular plate 108; a pair of like plate side walls 110, each having a configuration as shown in FIGURE 3 and a rectangular end wall 112 (towards the furnace). The aforementioned components are welded, or otherwise suitably secured together to form a watertight granulator tank of boat-like shape, in a manner known in the art.

One tank side wall 110 (the one shown in FIGURE 3) is provided with a rectangular cut-out 114 of suitable size to provide a weir 116 for overflow of water in the tank, indicated at 117. The water flows from the tank of granulator 82 into a rectangular-shaped water discharge box 119, from which it is in turn carried away through a discharge pipe 121 for suitable disposal. (A discharge or recirculating pump may be provided in pipeline 121, if necessary or desired.) The top of the water discharge box 119 is preferably open to permit water to overflow the box in the event (there is some sort of stoppage in the discharge pipe 121. An additional angle 122 is provided on the granulator tank side wall 110 which has the aperture 114 forming weir 116, so that the water discharge box 119 can be better supported between angles 102 and 104, as is especially apparent in FIGURE 3.

A suitable steel framework 120 is provided at the end of the granulator tank 82 nearest the furnace 20 to cradle the lower end of the front-flush slag chute 78 and the lower end of the ladle slag discharge chute 79 (or 79b, if the latter is made in two parts). This chute supporting framework 120 may comprise a pair of spaced channels 124 suitably secured in vertical position to the tank of the granulator 82, by welding or the like, with two horizontal channels 126 and 128 suitably secured between vertical channels 124, so as to cradle and support the ends of slag spouts 78 and 79 which overhang the end of the granulator 82 adjacent the furnace.

The end wall 112 of granulator 82 is provided with a pair of rectangular apertures that receive the forward ends of nozzles 130, which are shown in detail in FIGURES 5-7, with the nozzle comprising: a pair of like side plates 133 of a shape as shown; a pair of top and bottom nozzle plates 135 secured to the edges of side plates 133; a pair of like trapezoidal-shape plates 137 secured to the edges of plates 135, and also to a pair of like plates 141 which are also secured to the ends of plates 133, and a rectangular or base plate 143 secured to the rear edges of plates 137 and 141. The plates 133, 135, 137, 141 and 143 are preferably welded together to form the nozzle 130. The plate 143 is provided with an annular aperture 143a, and there is welded to the plate 143, around the aperture 143a, a coupling 143b which is adapted to have a conduit connected thereto, for the feeding of the cooling fluid, such as water, through the nozzles 130 into the granulator tank 82. As will be noted from FIGURE 7, the inside forward edges of top and bottom nozzle plates 135 are milled at 135a to form a rectangular passageway 135b, so that the water will exit
from the nozzle 130 in a flat wide jet. There are welded to the sides 133 of the nozzle 130 a pair of lugs 133a which have a plurality of apertures 133b whereby the nozzle 130 can be mounted on the granulator tank 82 by bolting the same to any suitable support means (not shown in the drawings), with the forward ends of the nozzle 130 extending through the rectangular apertures in granulator tank end wall 112 as previously indicated.

Water is fed through the nozzles 130 from conduits 131 under substantial pressure, supplied by suitable water pumps not shown, whereby the water is expelled from the rectangular openings 135b of each of nozzle 130 in a flat jet stream which spreads out somewhat in direction of the width of the granulator tank 82 near end wall 112. The hot slag which spills into the end of granulator tank 82 from the front flush chute 78 (and the ladle slag chute 79 in the embodiment of FIGURE 2) intercepts these flat streams of water from jet nozzles 130, thus causing the slag to be rapidly chilled and granulated. This results in the production of relatively finely divided discrete particles or pieces of solid metal, solid ferrous ore, non-ferrous slag and gongue. This granulation of the molten steel slag is achieved by a combination of mechanical disruption of the molten steel slag discharged into the granulator 82 and chilling of the slag by the water jet streams from nozzles 130 (particularly the upper nozzle).

The granulator 82 is provided with an endless scraper or rake-type flight conveyor, which is generally indicated by the numeral 132 and shown especially in FIGURES 3 and 4. This conveyor comprises a driven head shaft 134 which is mounted at each end in suitable bearings 136 supported on the upper longitudinal edges of the granulator tank 82, at the end nearer the furnace, with three toothed sprockets 135 non-rotatably secured thereon. The bearings 136 are mounted on the sides of the granulator tank 82 in any suitable manner, and preferably on a pair of larger-sized angles 139 of suitable length which are secured to the upper tank-frame angles 90 in any suitable manner to provide better supporting means for the bearings 136.

A tail shaft 140 is provided with its ends rotatably mounted in suitable bearings 142 on the sides of granulator tank 82 adjacent its "prow end," and has three tail shaft rollers 144 non-rotatably secured to shaft 140, each being in longitudinal alignment with one of the toothed sprocket wheels 138, as shown in FIGURE 3. An endless link-belt log chain 145 extends over each of the three sets of aligned sprockets 138 and tail rollers 144, with part of each chain being suspended near the bottom plates 106 and 108 of the granulator 82 as shown in FIGURE 3. A suitable chain for this purpose is the C131 "Link Belt" logging chain, with "F2" attachments which include portions for mounting of rectangular steel flights 146. Each of the flights 146 is secured to an upstanding portion of three corresponding transversely aligned 72 attachments in chains 145 by machine bolts, thereby providing a plurality of drag flights extending substantially across the width of the granulator tank 82 at small spaced intervals on the chains 145. Since the construction of such a C131 link belt logging chain with F2 attachments and flights is known in the art, and the components can be obtained commercially, further detailed disclosure and discussion thereof is deemed unnecessary.

The lower sections of the chain flight conveyor 132 are located near the tank bottom plates 106 and 108 so that the flights 146 will rake the granulated slag and metal in granulator 82 to the upper prow end of sloping bottom plate 108. The outer edges of the flights 146 slightly clear the bottom tank plate 106, thus causing formation of a small layer of granulated slag and metal particles on the tank bottom, which in effect form a "wear plate" that minimizes abrasive wearing of bottom tank plate 106. Because the tank plate 108 slopes so that the granulated particles of metal and slag will tend to slide to the bottom of the tank, these particles are not relied on as a "wear plate," but an additional wear plate 109 is usually provided on the inside of plate 106 for this purpose. The link chains 145 and 148 and the links 134 and 149, respectively, are adjusted so that the outer ends of the flights 146 will slightly clear this inside wear plate 109. Two additional elongated wear plates 111 are preferably also provided along the bottom inside of the main tank sides 110 to reduce wear of the slag walls 110 due to the abrasive action of granulated slag and metal particles moved along the tank bottom by flights 146 on chains 145.

A plurality of return idler roller shafts 147 are suitably rotatably mounted across the open top of the granulator tank, with three rollers 148 non-rotatably secured on each of shafts 147, to support at spaced points the upper cross bar of each of log chains 145 and flights 146. The ends of the return idler shafts 147 are suitably mounted in any suitable bearing on a suitable support means 149. Thus, for example, support means 149 may comprise a pair of spaced annular 151 extending transversely across the top of the granulator tank 82, with their ends welded or otherwise secured to upper tank edges 90; and short pieces of channel iron 153 secured between angles 151 over angles 90 to provide brackets for the bearings 147a in which the ends of idler shafts 147 are rotatably mounted.

The flight chain conveyor 132 is driven in the direction indicated by the arrows in FIGURE 3 by a variable-speed electric motor 150, which is suitably supported on or adjacent the granulator 82 and drivingly connected to the conveyor drive shaft 134 by suitable means such as a belt 154 driving pulley 152.

It will be noted that the slag can be discharged from the chute 78 (and chute 79, per FIGURE 2) into the water in granulator 82 through the flights 146 of the rake conveyor 142. Thus, continuous conveyor operation does not interfere with the discharge of the slag from the open hearth furnace into granulator 82, especially during the periods of maximum front slag flush when the slag may be thrown forward from the end of chute 78 as it spills into granulator 82.

As shown in FIGURE 3, one side wall 110 of granulator 82 is provided with a plurality of apertures 156, 158, 160, and 162, above the water line 117 (which is determined by the location of weir opening 114 and the quantity of water and granulated slag and metal in the granulator 82). A manifold 164, which has a configuration substantially as shown in FIGURES 4 and 5, is mounted on the side of the granulator 82 by suitable support means (not shown to permit clearer illustration of other parts); and manifold 164 includes lateral ducts 166, 168, 170 and 172 whose ends are suitably secured by a conventional gas-tight arrangement to the granulator side wall 110 around the apertures 156, 158, 160 and 162, respectively. Generally, the apertures 156, 158, 160 and 162, and their related manifold ducts 166, 168, 170 and 172, will progressively decrease in size as they are located nearer the "prow end" of the granulator tank 82, because less steam will have to be removed at the latter end than at the slag input end.

A pipe 174, including a conventional venturi 176, is suitably connected to an aperture in the rearward elbow of the manifold 164; and there is in turn coupled to this an air hose 178 for supplying air to the elongated main section of manifold 164. As will be apparent, the granulation of hot slag spilling from the chute 78 (and 79) into the water jets from nozzles 130 in granulator tank 82 may cause a substantial quantity of steam to be generated, and this must be removed from the "kitchen" 25 where the granulator 82 is located. Accordingly, during this granulating operation, air is supplied at a suitable pressure to the manifold 164 from the venturi inlet pipe 174, 176, and this creates an inspirator effect...
which lowers the pressure in manifold ducts 166, 168, 170 and 172, whereby the steam exits from the tank of granulator 82 through side apertures 156, 158, 160 and 162 into the main conduit of the manifold 164. The steam is then conducted through suitable conduits for disposal, as, for example, by venting to atmosphere through an opening in furnace building wall 22. If necessary or desired, an exhaust-fan arrangement capable of handling steam can be installed at the vent in building wall 22 or elsewhere in the steam conduit system connected to steam manifold 164 to assure adequate removal of steam, in light of such factors as quantity of steam, size of conduits, distance to venting, etc. As the particular construction of the steam discharge system is not a feature of the present invention, and suitable arrangements will be apparent to those skilled in the art, in light of this disclosure, further extended discussion thereof is believed unnecessary.

In addition to avoid having steam generated within the granulator tank 82 pass off into the "kitchen" 26 in objectionable quantities, unless the granulator 82 is preferably also provided with a suitable hood generally indicated at 180 in FIGURES 2 and 3. As illustrated, steam hood 180 comprises a suitable rectangular box-like framework, made up of pipe or wood members indicated at 182, and the upper part of sides of framework 182 is covered with a suitable material 184, such as heavy canvas, for preventing excessive egress of steam from the granulator 82 into kitchen 26. As illustrated in FIGURES 3 and 4, the steam hood 180 is supported over the tank of granulator 82 with one end spaced a sufficient distance from granulator end wall 112 so that the slag discharged into the granulator 82 from the chute 78 (and 79) does not spray the steam hood 180; and the other end of hood 180 is adjacent the "prow end" of the granulator 82. The steam hood 180 is supported in desired relation to the granulator 82, slightly clearing the top of conveyor flights 146 by any suitable means; preferably this is done by a plurality of chains or cables 186 secured at their upper ends to the ceiling of the "kitchen" 26, and at their lower ends to the steam-hood framework 182, as illustrated in FIGURES 2-4 of the drawings, whereby the steam hood 180 will "float" above the granulator, thus preventing rupture of the hood walls 184 by excessive steam. If desired, the steam hood 180 may be suspended from the ceiling of kitchen 26 by suitable conventional hoist means so that it can be conveniently raised to provide access to the parts of granulator 82 below the hood.

In FIGURE 13 during the granulation of slag in the granulator 82, as previously discussed, causes the resultant granulated particles of metal and slag to be dragged along tank bottom 166 and sloping plate 168 by flights 146 so that the granulated mixture is ultimately discharged from granulator 82 to an inclined chute 188 mounted at the upper prow end of the granulator (by any suitable support means not shown for clearer illustration of other parts in the drawings). The granulated mixture of slag and metal particles then spills from chute 188 onto an endless moving conveyor belt 190, which is of commercially available conventional type (and therefore is shown diagrammatically in the drawings, FIGURES 1 through 4). Referring now especially to FIGURE 1, the conveyor 190 transports the granulated relatively small particles of slag and metal, indicated by the numeral 192, out of the furnace building 22 through an enclosed aperture 194. In the illustrated embodiment, the conveyor 190 transports the mixture of granulated slag and metal from granulator 82 discharges this mixture 192 onto an endless belt conveyor 196, which runs along the outside of the building and is adapted to receive the discharge of metal and slag mixture 192 from each of the granulators 82 servicing each of the open hearth furnaces 20, as shown for two furnaces in FIGURE 1.

The endless belt conveyor 196 conveys the granulated mixture of metal and slag 192 to a continuously operating variable field magnetic-separator arrangement which is generally indicated at 196 in FIGURE 1 and diagrammatically shown in FIGURE 2, to which reference is now made. The end pulley 200 of the main conveyor 204 belt carrying the slag-and-metal-particle mixture 192 is magnetic; and there is disposed adjacent and substantially parallel to the magnetic pulley 200 a "splitter" 202 having a configuration and position as illustrated in FIGURE 8. 199

As the particles of slag and metal mixture 192 on the conveyor belt 195 pass over the magnetic separator 196, the magnetic ferrous particles, indicated at 192a, adhere to the belt 196 to sufficient extent so that they fall to the side 202a of the splitter bar 202, and thence onto another conveyor belt 204 which carries these magnetic particles to a suitable disposal point for ultimate re-use in the furnace. The non-magnetic particles, indicated by the numeral 192b, do not adhere to the magnetic end pulley 200 and are in effect thrown over to the other side 202b of the splitter bar 202, and thence onto another endless conveyor 206 which carries these non-ferrous particles off to a suitable disposal, as diagrammatically shown in FIGURE 1.

The conveyor-and-magnetic-separator means 196 is known and its components are commercially available and the particular construction of conveyor-and-separator means 196 does not per se form a part of the present invention, so that further discussion thereof is believed unnecessary. As shown in FIGURE 1, the ferrous material which has been thus magnetically separated from the non-ferrous slag may be transferred by conveyor 206 directly to a suitable hopper 208, from which the ferrous material may be loaded onto trucks 76a for transport to the open hearth furnace building for re-use when desired.

While FIGURES 1 and 8 illustrate a preferred system for continuously transporting granulated slag and metal from the several granulators 82 in the furnace building 22, with a conveyor-and-magnetic-separator system for separating the ferrous material from the non-ferrous slag in a continuous operation, it will be understood that the granulated mixtures of metal and slag from granulators 82 can be discharged from the associated conveyors 190 to some other suitable transport means, such as box cars on rail spurs along the side of the furnace building 22, or hydraulic pipeline transportation, etc. The particular means for conveying the granulated mixture of metal and slag from the respective furnace granulators and out of the plant building 22 will depend on the open hearth furnace layout and geography and location of other mill installation. Suitable modifications of the preferred arrangement shown in FIGURE 1, according to such factors will be apparent to those skilled in the art, in light of the disclosure herein.

Referring back to FIGURE 2, as has been previously mentioned, the front-flush slag conveyor 78 is movable by hoist means generally indicated at 80, for reasons that will now be amplified together with a more detailed description of the slag chute moving means 80 which is disclosed in more detail in FIGURES 9 and 10 to which reference is now made.

As shown particularly in FIGURE 10, the front-flush slag chute 78 comprises an elongated runner and boot section 78b and an enlarged head end 78c" with a configuration as illustrated. The chute 78 is made of cast steel, with a radius at all angles to facilitate free flow of the slag in the chute, which may also be coated with a suitable refractory material if desired. Each side of the chute 78 is provided with a pair of lugs 99 near the boot end of the chute and 99 near the head end of the chute.

Boot end lugs 99 are attached to a cable or chain 85, and head end lugs 99 are connected to a cable or chain 87, with the boot end cable or chain 85 being part of a hoist 89 and the head end cable or chain 87 being part of a hoist 91. Chain hoists 89 and 91 are mounted on trucks 93 and 95, which are in turn movably mounted on a
monorail 97 suspended from the ceiling of the kitchen 26 in any suitable manner, as diagrammatically illustrated in FIGURE 9. As will be apparent from FIGURES 9-10 (and FIGURE 2), the head end 78" of chute 78 extends through the aperture 25 in the upper part of the vertical wall 27 which separates the kitchen 26 from the pit 68 below the furnace 20; and, if desired, the underside of the chute 78 can be cradled on the bottom portion 250 of this wall aperture. A four-sided rectangular steel spillway 66a is suitably mounted in front of the center charging door 40 and below the front-flush trough 62. Thus, when the front-flush slag chute 78 is in its normal position A shown in solid line in FIGURE 9, with its boot end extending over the input end of the granulator 82 (which is only diagrammatically shown in FIGURE 9), the slag 64 flushed from the front of furnace 20 is discharged through the spillway 66a into the head end 78" of chute 78. The slag then will pass down the chute 78, which is generally at an angle of about 35° from horizontal, and spill from the boot end 78" into the granulator 82 where it is converted to granular particles of slag and metal, as previously explained. If, for some reason, it is desired not to use the slag granulator 82, the head end 78" of the chute 78 is raised by hoist 91 and cable 87 to the dotted-line position B in FIGURE 9, whereby chute head end 78" is removed from the path of the front-flushed slag, which is determined by the spillway 66a; the boot end 78" of the chute 78 is also raised by the hoist 89 and cable 85 so that the chute is then in the dotted-line position C in FIGURE 9, with its head end 78" still clear of the front-flush slag spillway. Then the slag chute 78 is removed away from the furnace, if desired or necessary, by movement of hoist trucks 93 and 95 along monorail 97, which can be done by suitable remotely operated motor and control means. The size of the chute 78, the location of hoist cable chutes 99 and 92, the normal location of the hoist means 87, 89, 91 and 93 can be predetermined with respect to the spillway 66a by kinematics, so that the chute 78 will travel an appropriate path for withdrawal from its normal position for conveying front-flush slag to the granulator 82. This arrangement makes it possible to promptly divert molten front-flush slag (or steel) 64 to the slag grade 72 and the pit 68 below furnace 20, for removal by current practices described above, when necessary or desirable; e.g., in the case of a furnace "reaction" or "break out" there would be a sudden increase of load on the granulator 82 which could create a dangerous condition if the surge of molten slag (and/or steel) were not diverted.

Suitable hoist and monorail trucks means, such as diagrammatically indicated at 85, 87, 89, 91, 93, 95 and 97 are commercially available, and arrangements for employing them in a system according to FIGURE 9 will be apparent to those skilled in the art in light of the present disclosure, so that a more-detailed showing and discussion thereof is believed unnecessary, especially since the particular details of these chute hoist means are not per se a part of the present invention.

Referring again to FIGURE 10 the kitchen side of wall 27 may be provided with a steel door 101 mounted in suitable vertical slideways 103 on each side of wall aperture 25, with cables 105 attached to said door 101 and operated by motor-driven hoist means (not shown). Thus, when the front-flush granulator slag runner 78 is withdrawn by 66a to divert front-flush slag to the slag grade 72 in pit 68 below the furnace, the door 101 can be also raised to cover opening 25 in wall 27 to prevent any front-flush slag from spilling into the kitchen 26.

Referring back to FIGURE 2, the hoist means 83 for moving the upper section 79a of the ladle slug chute 79 in this embodiment may be like the above-described front-flush slag chute hoist means 89. Accordingly, a suitable construction for hoist means 83 will be apparent to those skilled in the art and further discussion thereof is believed unnecessary. It is also noted, however, that hoist means 83 for the upper ladle slag chute portion 79a could comprise a single hoist and chain connected to lugs on the opposite sides of the chute section 79a so as to cause that chute section to pivot around its lower end which is nested in the upper end of lower chute portion 79b (i.e., in the region indicated by numeral 79c in FIGURE 2). Such arrangements permit withdrawal of the ladle slag chute end of the FIGURE 3 embodiment from adjacent the steel ladle 50, if and when desired.

Another preferred embodiment for granulation of open hearth steel furnace front-flush slag according to the present invention with a preferred movable-chute arrangement for transferring molten slag to a granulator (like 82) in the kitchen 26 away from the charging floor spillway 66 and promptly diverting the molten slag from the granulator to below the furnace, when desired, is disclosed in my copending application Ser. No. 304,912 on "Steel Slag Handling System," filed Aug. 27, 1963, as a continuation-in-part of my aforementioned patent application Ser. No. 126,792, filed June 28, 1961; and the disclosure of my said application Ser. No. 304,912 is incorporated herein by reference as though fully set forth herein (said application Ser. No. 304,912 has been abandoned in favor of copending application Ser. No. 351,168 on Steel Slag Handling System, filed May 18, 1964).

Referring to FIGURE 11, there is shown a modification of the new improved slag-removal system of this invention described above with reference to FIGURE 2, in that the arrangement for granulating and handling the steel ladle slag differs from the arrangement shown in FIGURE 2.

More specifically, the slag-removal system of FIGURE 11 is the same as that described with reference to FIGURES 1-10, except that the ladle slag discharge chute 79 shown in FIGURE 2 is omitted together with related parts such as apertures 31 in the wall 27, the cradle 128 on granulator 83 for the boot end of the charging floor spillway 66 and promptly diverting the molten slag from the granulator to below the furnace, when desired, is disclosed in my copending application Ser. No. 304,912 incorporated herein by reference as though fully set forth herein (said application Ser. No. 304,912 has been abandoned in favor of copending application Ser. No. 351,168 on Steel Slag Handling System, filed May 18, 1964).

In lieu of the steel ladle slag removal chute 79, etc., in the system of FIGURE 2, the system of FIGURE 11 includes another granulator 82b on the pit side 28 of the furnace building for granulating slag discharged from the steel ladles 50 of the various open hearth furnaces 20. The granulator 82b is of the same construction as the granulator 82 in the kitchen 26 described above with particular reference to FIGURES 3-7, but is of a smaller size since the ladle slag comprises about 35% of the total slag per heat, whereas the front-flush slag comprises about 65%. For convenience, major comparable parts of the ladle slag granulator 82b are identified in FIGURE 11 by like numerals as corresponding parts of granulator 82 in FIGURES 3-7 plus the letter b; and detailed description thereof is believed unnecessary, since the mode of operation of granulator 82b is the same as that of granulator 82 installed in kitchen 26 to handle the front-flush slag in this system (as in that of FIGURE 2).

The steel ladle slag is discharged into a separate granulator 82b on the pit side of the furnace room, while the front-flush slag is being handled by a granulator 82 in the kitchen of the furnace room, as described above. More particularly, in this embodiment, the slag spout 58 on each steel ladle 50 is aligned with the tap hole of the furnace 20, but extends from the ladle 50 on the side away from the furnace 20, whereby the steel ladle slag overflows into a slag chute 79f from which it spills into the jet stream end of granulator 82b, which is like the granulator 82 of FIGURES 2 and 3, but is of smaller size and is suitably mounted on a rail car of conventional construction, in a manner that will be apparent to those skilled in the art. The granulator 82b can be moved along rails 212 on the pit floor, running parallel to the line of the furnaces 20, so that the granulator 82b can be positioned with chute 79e at the particular steel ladle 50 for the fur-
The chute 79f can be supported between the steel ladle slag spout 58 and the jet-stream end of the granulator 82b in any suitable manner: one suitable system is to mount the chute 79f on a chain or cable hoist that is movable on an overhead monorail along the length of the furnace 20 parallel to the track 21 for convenient removal from ladle 50 and transfer of chute 79f along with the granulator 82b to the next steel ladle to be tapped. The conveyer means 190 which receives the granulated mixture of slag and metal particles (192c) from the chute 188b at the prow discharge end of the granulator 82b is set up, in a manner known in the art, so that conveyer 190b can be moved to behind each of the various furnaces 20 in the open hearth plant, for suitable removal from the furnace building of the steel ladle 50 granulated in the granulator 82a. The steam hood 180b is suitably mounted on the granulator 82b, and a suitable steam-removal arrangement, water input means, and air input means are provided for granulator 82b to permit mobility.

While it is believed that the operation of the new improved slag-removal system of the present invention will be apparent from the foregoing description thereof with reference to FIGURES 1 through 11 (and 12) the mode of operation of the system will be briefly summarized: During the steel-making operation in the open hearth furnace, about 65% of the slag is front flushed through the trough 62 cut in the refractory front furnace wall 30 below the center front furnace door 40 into the spillway 66a, whence this hot molten slag falls into the head end of the front-flush slag chute 78. The hot slag then spills into the rear end of the granulator 82, and intercedes the two horizontally extending jets of water emitted from the upper and lower nozzles 130. The molten slag is broken up by force of the jets and rapidly chilled by the water jet streams in the air above the level of water bath 117 in granulator 82, thus converting the slag into a relatively finely divided granulated solid product which consists of discrete particles of solid metal and solid slag, with the metal particles being substantially free of adhering slag, so that the metal and slag particles may later be readily separated. The granulated particles of metal and slag fall into the water bath 117 in the bottom of the tank of granulator 82, where they are further cooled. Particles of slag which are still sufficiently hot may be further granulated to some extent in water bath 117, particularly in conjunction with the action of rake conveyor 132 which moves the resultant granulated particles of metal and slag falling to the bottom of the granulator tank so as to discharge the granulated slag from the upper prow end of granulator 82 to a transport means such as chute 188 and associated continuous belt conveyor 190.

The rake conveyor 132 within granulator 82 is an advantageous feature of the steel-slag granulating system of this invention because: (a) The flights 146 of the rake conveyor 132 moving granulated slag through the water bath 117 below the level determined by weir 118 agitate the water bath, thereby preventing the accumulation of steam and/or gas pockets by reason of slag being insufficiently cooled when it falls into the bath 117, thus avoiding explosions. (b) Flights 146 of rake conveyor 132 also tend to break up any relatively large pieces of slag flowing into water bath 117, facilitating granulation and cooling thereof. (c) The rake conveyor 132 conveys granulated slag away from water jet nozzles 130, preventing the accumulation and pileup of slag in front of the nozzles 130 (which may otherwise occur, particularly at a high rate of slag tonnage feed to the granulator 82), and also preventing the build-up of any "hot spots" in accumulated slag pilesup.

(d) The rake conveyor 132 promptly removes the granulated slag from the water bath 117 and carries it up the slope 108 of the prow end of granulator 82, the slag is further cooled in the air, and steam and/or gas can readily escape to the atmosphere. (e) The rake conveyor 132 continuously and rapidly positively displaces and removes large tonnages of granulated steel slag, even as it is being discharged from the feed end of the granulator 82 where slag tonnages from a modern steel furnace can be handled by a rather small granulator which can be installed near the furnace in the limited space available in existing steel furnace buildings (e.g., an open hearth kitchen), without interfering with normal steel-making practice. Hence, this rake-conveyor arrangement in granulator 82 provides a safe, practical, commercially usable system, although other equivalent means may be provided to achieve such mode of operation and results. Steam formed during the granulating of the slag is carried off from granulator 82 through manifold 164 and related conduits due to the air input from pipe 174, and is ultimately vented to atmosphere; and hood 180 prevents undue spread of steam in kitchen 26.

Conveyor 190 carries the granulated slag from the furnace building 22 (according to the layout of the furnace plant). Preferably, the plurality of granulators 82 in the "kitchen" of the open hearth plant discharge the granulated slag and metal to a common conveying and magnetic separator means for continuously separating the ferrous and slag particles and transferring them to suitable disposal points (as in the embodiment illustrated in FIGURE 1). When the furnace is tapped, the remaining 35% of the melt slag discharged to the top of steel ladle 50 after the tapping of the steel is also fed to a granulator which converts this slag to relatively small discrete particles of metal and slag, in like manner as the front-flush slag. As disclosed above, the steel ladle discharge slag may be transferred to the kitchen side of the furnace for granulation in the same unit 52 which granulates the front-flush slag, and subsequent removal from the furnace building 22 by the same conveyor system 190. Or, if this is not suitable for a given open hearth furnace installation, the steel ladle slag may be granulated in another granulator on the pit side of the furnace, and the resultant mixture of metal and slag particles carried away from the furnace and out of the furnace building by another associated conveyor means, for later separation of the ferrous metal from non-ferrous slag (as illustrated and described with reference to FIGURE 11). The water discharged from the granulator 82 to conduit 121 may be disposed of or recycled for reuse in the granulator (preferably after removing solids therefrom by settling or by the like). Factors which are relevant to use of this new improved slag granulating-and-removal method and apparatus and determination of the particular size and design of the equipment involved, include the following:

(a) temperature of slag discharged from the furnace (front-flush slag, and ladle slag, respectively);
(b) quantity of front-flush and ladle slag discharged per minute into the granulator, especially at maximum rate;
(c) the pitch of the chute(s) conveying the slag from the furnace to the granulator (and slag viscosity);
(d) the size, shape and location of the granulator jet nozzles in relation to such features as the over-all size of the granulator, quantity of slag handled, especially at maximum rate, etc.;
(e) the input water pressure to the granulator jets;
(f) the ratio of water input to slag input for a given time period;
(g) the input water temperature; and
(h) the quantity of steam generated, and capacity of the steam-removal facilities provided.
and 7 1/2 feet high at the prow end, and about 5 1/2 feet wide; and the upper and lower nozzles 130 are respectively located about one foot and 1 1/4 feet from the upper edge of the tank end wall 112. Water is fed to nozzles 130 at sufficient pressure, e.g., 35–60 p.s.i., and in sufficient amount, to produce substantially instantaneous solidification and generation of the slag into molten and non-metallic particles of sizes running less than 1/2 inch in dimension, with the slag particles being friable and readily crushed or ground.

Water or a liquid of comparable characteristics must be used as the liquid for the jet stream and cooling medium in the molten steel slag system according to the system herein disclosed. However, because of its availability in large quantity at low cost, water is the only presently known liquid which is commercially usable for the steel slag granulation system of this invention.

For convenience, the granulation system of FIGURES 1–10 may be considered as having three mutually perpendicular reference axes, indicated at x, y and z in FIGURES 3 and 4 (and also in FIGURES 5–7). In the illustrated embodiment, the length of granulator 82 extends in the direction of horizontal axis x (FIGURES 3 and 4), and other components extending in the direction of vertical axis y (FIGURE 3), and with side wall and other components extending vertically as indicated at y in FIGURE 3, and with other components extending transversely to the granulator's longitudinal axis x as indicated at z in FIGURE 4. Referring to FIGURES 3, 4 and z axes per FIGURES 3 and 4, are shown for convenience reference, each water jet nozzle 130 is provided with a flat rectangular machining opened 135b formed by machined plate sections 135b and vertically disposed side plates 135 which extend in the direction of the granulator’s longitudinal axis x so that a flat wide water jet is emitted horizontally from nozzle 130 in the direction of axis x. It has been found that the width of the rectangular aperture 135b of nozzle 130, in the direction of granulator’s transverse axis z, should preferably exceed by at least 10% the width between the inside of the side walls 211 of the end portion of the slag chute (see w in FIGURE 10) from which the molten steel slag is poured into the water jet of granulator 82, when the centerline of said end portion of the slag chute crosses the centerline of each water jet nozzle 130, as illustrated. If, however, the chute and nozzles do not have their centerlines so aligned, then the width of nozzle opening 135b and the width w of the end portion of the slag chute at granulator 82 should be such that each slag chute side wall 211 is located in transverse direction z so that each side wall 133 of water nozzle 130 is disposed outside or beyond the respective chute wall 211 a distance equal to at least 5% of the chute width. Slag chute end 78' should not extend any substantial extent in the direction of the transverse horizontal axis z, to avoid feeding molten slag with any substantial trajectory in the direction of axis z transverse to the water jet stream injected in direction of axis x. Thus, the slag chute 78 should extend in the direction of the longitudinal axis x when slag is being poured into the granulator 82, as shown in FIGURES 1–4, 9 and 11, and also as shown in FIGURES 1–3 of my aforesaid copending application Ser. No. 304,932, incorporated herein by reference (said FIGURES 1–3 showing the chute in granulation operating position for the latter embodiment). It is desirable to make the slag chute end portion 78' feeding the granulator 82 with substantially parallel side walls 211 extending for a sufficient length in the direction of the longitudinal reference axis x to assure a proper molten slag trajectory with reference to the water jet stream from nozzles 130. That is, it is preferable not to use a slag chute whose end portions adjacent granulator end wall 112 have non-parallel side walls extending in the direction of transverse reference axis z at a substantial angle to horizontal reference axis x.) However, the nozzles 130 may be tilted slightly up or down in direction of vertical reference axis y, so as to be at a slight angle to horizontal reference axis x.

It has been found that to achieve efficient magnetic separation of commercially usable ferrous material from steel slag into metal and non-metallic particles of sizes running less than 1/2 inch in dimension, with the slag particles being friable and readily crushed or ground.

Water or a liquid of comparable characteristics must be used as the liquid for the jet stream and cooling medium in the molten steel slag system according to the system herein disclosed. However, because of its availability in large quantity at low cost, water is the only presently known liquid which is commercially usable for the steel slag granulation system of this invention.

For convenience, the granulation system of FIGURES 1–10 may be considered as having three mutually perpendicular reference axes, indicated at x, y and z in FIGURES 3 and 4 (and also in FIGURES 5–7). In the illustrated embodiment, the length of granulator 82 extends in the direction of horizontal axis x (FIGURES 3 and 4), and other components extending in the direction of vertical axis y (FIGURE 3), and with side wall and other components extending vertically as indicated at y in FIGURE 3, and with other components extending transversely to the granulator's longitudinal axis x as indicated at z in FIGURE 4. Referring to FIGURES 3, 4 and z axes per FIGURES 3 and 4, are shown for convenience reference, each water jet nozzle 130 is provided with a flat rectangular machining opened 135b formed by machined plate sections 135b and vertically disposed side plates 135 which extend in the direction of the granulator’s longitudinal axis x so that a flat wide water jet is emitted horizontally from nozzle 130 in the direction of axis x. It has been found that the width of the rectangular aperture 135b of nozzle 130, in the direction of granulator’s transverse axis z, should preferably exceed by at least 10% the width between the inside of the side walls 211 of the end portion of the slag chute (see w in FIGURE 10) from which the molten steel slag is poured into the water jet of granulator 82, when the centerline of said end portion of the slag chute crosses the centerline of each water jet nozzle 130, as illustrated. If, however, the chute and nozzles do not have their centerlines so aligned, then the width of nozzle opening 135b and the width w of the end portion of the slag chute at granulator 82 should be such that each slag chute side wall 211 is located in transverse direction z so that each side wall 133 of water nozzle 130 is disposed outside or beyond the respective chute wall 211 a distance equal to at least 5% of the chute width. Slag chute end 78' should not extend any substantial extent in the direction of the transverse horizontal axis z, to avoid feeding molten slag with any substantial trajectory in the direction of axis z transverse to the water jet stream injected in direction of axis x. Thus, the slag chute 78 should extend in the direction of the longitudinal axis x when slag is being poured into the granulator 82, as shown in FIGURES 1–4, 9 and 11, and also as shown in FIGURES 1–3 of my aforesaid copending application Ser. No. 304,932, incorporated herein by reference (said FIGURES 1–3 showing the chute in granulation operating position for the latter embodiment). It is desirable to make the slag chute end portion 78' feeding the granulator 82 with substantially parallel side walls 211 extending for a sufficient length in the direction of the longitudinal reference axis x to assure a proper molten slag trajectory with reference to the water jet stream from nozzles 130. That is, it is preferable not to use a slag chute whose end portions adjacent granulator end wall 112 have non-parallel side walls extending in the direction of transverse reference axis z at a substantial angle to horizontal reference axis x.) However, the nozzles 130 may be tilted slightly up or down in direction of vertical reference axis y, so as to be at a slight angle to horizontal reference axis x.
Water should be introduced to granulator 82 at a quantitative rate in gallons per minute varying in relation to the rate at which molten steel furnace slag is poured into the granulator 82 as follows: (a) Water should be introduced into granulator 82 at the slag input end (adjacent wall 112) at an average rate of at least about 400 g.p.m. per ton of steel slag per minute poured into the granulator. (b) Water should be preferably introduced at the slag input end of the granulator 82 at an average rate of about 900-1350 g.p.m. per ton of steel slag per minute poured into the granulator. (c) And, it is best to use at least about 1350-1600 g.p.m. per ton of steel slag per minute poured into the granulator to avoid objectionable vaporization and formation of steam. The input water preferably should be at typical water-main temperature (e.g., 60° to 70° F.); however, furnace-cooling water or other plant-used water may be employed, but its temperature preferably should not exceed 100° F.

(3) It is preferable that the amount of water per paragraph 2 be introduced into granulator 82 by means of the jet nozzles 130 in such quantitative g.p.m. rates according to varying molten steel slag tonnage input rates. However, in the disclosed embodiment of FIGURES 2-7, the size of the disclosed jet nozzle 130 is such that desired water jet velocities and g.p.m. per parts (a), (b), (c) and (d) of paragraph 1 above frequently can be achieved with a lower quantity of water through the nozzle(s) 130 than required to meet the conditions of part (a), (b) or (c) of paragraph 2. In such event, it is possible to introduce the requisite water per paragraph 1 through the jet nozzle(s) 130 to achieve at least the water jet velocities and g.p.m. set forth in paragraph 1 above, and to introduce the remainder of the water per paragraph 2 by other means; e.g., a water pipe of suitable size may be secured to end wall 112 of granulator 82 below the lowest nozzle 130, at point 220 or 222 in FIGURE 3, to supply additional water to granulator 82 by conduit from a suitable source. However, the safest and best approach is to introduce all water requirements per paragraph 2 into granulator 82 through the water jet nozzle(s) 130. This increases the effectiveness of the water jets for breaking down the molten steel slag into small particles to achieve more rapid and more efficient slag cooling and granulation, and helps assure smaller resultant granulated slag particles for better magnetic separation and also more efficient hydraulic slurry transportation (in those shops where it is preferable to a conveyor-belt system).

(4) Still, the foregoing good results can be achieved by operating the granulator system of this invention using two flat jet streams of water injected horizontally into granulator 82 through two like-size nozzles 130, one over the other, according to the following: (a) For molten slag input of up to about 2 tons per minute, inject two water streams with jet velocity of about 36.5 to 61 f.p.s., and about 1200-2000 g.p.m. through both jets. (b) For a molten slag input rate of 2 to about 4 tons per minute, inject two water jet streams at a velocity of at least 61 to 122 f.p.s., and about 2000-4000 g.p.m. through both jets. (c) For a molten slag input rate of about 7 tons per minute, inject two water jet streams at a velocity of at least about 91 to 146 f.p.s., and about 3000-5000 g.p.m. through both nozzles.

(5) Granulation of the molten steel slag is generally largely accomplished by the flat water jet stream from the upper nozzle 130, with the lower water jet stream from lower nozzle 130 opening the jet stream containing the lower nozzle 130 also providing a safeguard against malfunction of the upper water jet while molten steel slag is being poured. Thus, more effective granulation of the molten steel slag may be achieved by injecting 3% to 9% (60-75%), and preferably 5% (66.6%), of available water through the upper of the two like-size nozzles 130 (14" x 14" opening, one over the other, aligned), and injecting the balance of the water through the lower nozzle. Thus, in light of the foregoing, good results can be achieved according to the following: (a) For a molten slag input rate of up to about 2 tons per minute and using water available at about 1200-2000 g.p.m., inject about 800-1530 g.p.m. (5%) through the upper nozzle 130 at about 49 to 82 f.p.s., and about 400-650 g.p.m. (15%) through the lower nozzle 130 at about 25 to 39.5 f.p.s. (b) For a molten slag input rate of 2 to about 4 tons per minute and using water available at about 2000-4000 g.p.m., inject about 1350-2700 g.p.m. (15%) through the upper nozzle 130 at about 82 to 164 f.p.s., and about 650-1300 g.p.m. (15%) through the lower nozzle at about 39.5 to 79 f.p.s. (c) For a molten slag input rate of 4 to about 7 tons per minute and using water available at 3000-5000 g.p.m., inject about 2000-3350 g.p.m. (35%) through the upper nozzle 130 at about 122 to 202 f.p.s., and about 1000-1650 g.p.m. (15%) through the lower nozzle at a velocity of at least about 61 to 101 f.p.s.

Operation of granulator 82 per the foregoing, especially per the conditions of paragraphs 4 and 5, provides resultant granulated steel slag of desirable particle size for efficient magnetic separation of ferrous materials. One efficient, hydraulic transportation per discussion above (see column 19, lines 59-75 and column 20, lines 1-33 hereof). The water may be supplied to one or both nozzles 130 through each of conduits 131 by conventional pump means at suitable pressure and in suitable quantity to achieve the desired nozzle jet stream velocity and g.p.m. input per paragraph 1 above, the desired g.p.m. water input per paragraph 2 above, or the preferred jet velocities and g.p.m. per paragraph 4 or paragraph 5 above, according to varying rate of steel slag feed to the granulator with different size steel furnaces, in a manner which will be apparent to those skilled in the art in light of the disclosure herein and using known scientific and engineering information.

By way of example, referring to operating conditions per paragraph 4 above, with like nozzles 130 of granulator 82 having a rectangular jet aperture 1350 of about 14 inches by ¾ inch in cross-section, and a 4½ inch I.D. section at 1436 connected to conduit 131, water supplied at 35 p.s.i. to each nozzle 130 may be injected into the granulator 82 at about 68 f.p.s., and about 1100 g.p.m. from each nozzle, and thus 2200 g.p.m. from both, according to the suggested operating conditions of paragraph 4 above. As another example, if granulator 82 has nozzle 130 having a rectangular aperture 1350 of 22 inches by ¾ inch in cross-section (e.g., for use with a slag chute 78 having a width w of 20 inches) with a 4½ inch I.D. section at 1436 connected to conduit 131, water supplied at 35 p.s.i. may be injected into the granulator 82 at about 75.5 f.p.s., and about 1590 g.p.m. from each nozzle, and thus 3900 g.p.m. from both, according to suggested operating conditions of paragraph 4 above.

Referring to paragraph 5 above, the thickness of one or both nozzles 130 may be modified to analogously use more than half of available water in the jet stream from the upper nozzle and less than half in the lower jet stream. Thus, the opening 132b of upper nozzle 130 may have a thickness (in direction of axis y) greater than the thickness of opening 132b of lower nozzle 130, both the upper and lower nozzles having an opening 132c with like width in direction of reference axis z. For example, the upper nozzle 130 may have an opening 132b of 14 inches by ¾ inch while the lower nozzle 130 may have an opening of 14 inches by ¾ inch. Thus, by way of example, a molten slag input nozzle of up to 2 tons per minute and using 2000 g.p.m. available water, 1200 g.p.m. (60%) would be injected through the top nozzle at 49 f.p.s. and 800 g.p.m. (40%) through the lower nozzle at 49 f.p.s.

When high water jet stream velocities are used, it may be desirable to suspend a series of chains across the path of the jet stream(s) to intercept the jets and reduce splash.
and spray at prow end 163 of granulator 82. Thus, referring to FIGURES 3 and 4, a bar (not shown) may be attached to two top angles 90 on the two granulator side walls 110, at a longitudinal location between vertical angles 100 and 102, and extending across the top of the granulator tank parallel to take conveyor shafts 147, below the upper portion of rake conveyor chain 145. A series of ordinary heavy-duty chains are secured from this bar, 163, at suitable intervals, e.g., 2 inches apart (in the direction of transverse axis x), with a length such that the end of each chain normally extends slightly below the level of weir 116, and thus below the usual operating level of water bath 117.

Open hearth or front-flush steel slag is typically discharged over a period of about 30 to 75 minutes, at a varying rate of up to about 2 tons per minute; however, the discharge rate may be much higher in the case of a "furnace reaction" or a "breakout." The present invention provides an effective system for rapid continuous granulation of front-flush slag adjacent the furnace and removal from the building where slag granulation is in process. Further, location of granulator 82 away from below the front-flush spillway 66 with replaceable means for transferring molten front-flush slag to the water jets of granulator 82 or diverting it to beneath the furnace provide important operating advantages, as in the case of a breakout or furnace reaction which also discharges a substantial quantity of molten steel through charging floor spillway 66. Open hearth tap or ladle slag is generally discharged from the top of ladle 50 seen in FIGURE 12 in a relatively short time in a large quantity (e.g., 20 tons in 3.5 to 4 minutes); this can be granulated adjacent the furnace using the present invention. Large tonnages of OSM or BOF steel slag may also be quickly granulated with the present invention using above-discussed operating conditions.

It will be apparent from the foregoing that the present invention provides a new improved slag-removal system which departs from the materials-handling concepts of the above-discussed current and earlier slag-removal systems, thereby avoiding their serious shortcomings by converting the very hot slag discharged from the open hearth furnace to relatively small discrete particles of ferrous metal and non-ferrous slag at low temperature, which can then be readily transported from the open hearth furnace building by continuous conveyor means; that the present invention provides such a new improved open hearth slag-removal system by which the granulated slag and ferrous material can be conveyed directly in magnetic or suspended means for quick, efficient, and economical separation of re-useable ferrous metal from the non-ferrous slag, and suitable disposal of each; and that the present invention is capable of complete removal of large quantities of red-hot slag produced in large-tonnage open hearth furnaces a very short time after the furnace is tapped, whereby slag removal no longer constitutes a "bottleneck" preventing optimum use of presently known oxygen techniques and shorter heat times in large-capacity open hearth furnaces; and that the present invention also achieves other important objects and advantages as discussed earlier in this application.

**Claim language definition.**—(1) The terms "ferrous material(s)" and "ferrous pieces (or particles)" as used in the claims means material which is usable in the making of iron or steel. (2) The terms "water" and/or "liquid" as used in the claims means water or an equivalent liquid having like characteristics, such as having been clarified from a gas or steam. (3) Recitation in the claims of the "x, y and z axis (or axes)" refers to the respective horizontal reference axis x, the vertical axis y, and the transverse horizontal axis z, as indicated at x, y, and z in the drawings and discussed above.

The present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced herein.

What is claimed and desired to be secured by United States Letters Patent and which forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced herein.

1. A method of handling molten steel slag characterized in that it comprises: pouring molten steel slag into a receptacle; injecting at least one jet stream of water into said receptacle so as to inject said molten steel slag to granulate the molten steel slag into particles; the water stream being injected with a jet velocity of at least about 25.0 f.p.s. and at least about 400 g.p.m. for a molten slag input rate of up to about 2 tons per minute, the water stream being injected with a jet velocity of at least about 30 to 36.5 f.p.s. and at least about 500 to 600 g.p.m. for a molten slag input rate of 2 to about 4 tons per minute, the water stream being injected with a jet velocity of at least about 36.5 to 55 f.p.s. and at least about 1200 to 1800 g.p.m. for a slag input rate of 4 to about 7 tons per minute, and the water stream being injected with a jet velocity of at least about 55 to 61 f.p.s. and at least about 1800 to 2000 g.p.m. for a slag input rate of 7-8 tons per minute; maintaining water accumulating in said receptacle at a level below said jet stream while said molten steel slag is being poured into the receptacle so that the molten steel slag intercepts said jet stream above water accumulated in the receptacle; and removing resultant granulated slag particles from said receptacle while the granulation of the molten steel slag is in progress.

2. A method of handling molten steel slag as defined in claim 1 wherein water for the granulation of the molten steel slag is provided at the rate of 400 to 1600 g.p.m. per ton of slag per minute.

3. A method of handling molten steel slag as defined in claim 1 wherein water for the granulation of molten steel slag is provided at the rate of about 900 to 1350 g.p.m. per ton of slag per minute.

4. A method of handling molten steel slag as defined in claim 1 wherein water for the granulation of molten steel slag is provided at the rate of about 400 to 1600 g.p.m. per ton of slag per minute.

5. A method of handling molten steel slag as defined in claim 1 wherein water for the granulation of molten steel slag is provided at the rate of about 1350 to 1600 g.p.m. per ton of steel slag input per minute.

6. A method of handling molten steel slag as defined in claim 1 wherein: for a steel slag input rate of 4 to about 7 tons per minute, water is supplied by means of two flat jet streams, one over the other, each having a jet velocity of at least about 36.5 to 55 f.p.s. with at least about 1200 to 1800 g.p.m. water being injected by means of both jet streams; and, for a molten slag input rate over 7 tons per minute, water is supplied by means of two flat jet streams, one over the other, each having a jet velocity of at least about 55 to 61 f.p.s. with at least about 1800 to 2000 g.p.m. being supplied by means of both jet streams.

7. A method of handling molten steel slag as defined in claim 1, further comprising: injecting at least one jet stream of water into a receptacle, the water being supplied by means of at least two flat jet streams, one over the other, with 60% to 75% of total water g.p.m. input being injected by means of the upper jet.
stream and 40% to 25% of said total water g.p.m. input being injected by means of the lower jet stream; each jet stream having at least a jet velocity in f.p.s. according to varying steel slag input rates as stated in claim 6.

9. A method of handling molten steel slag characterized in that it comprises: pouring molten steel slag into a receptacle; injecting into said receptacle a plurality of flat jet streams through a plurality of nozzles having substantially rectangular apertures and disposed one over the other and spaced from each other with the trajectory of said water jet streams intercepting the path of the slag; said water jet streams being injected with a jet velocity of at least about 35 to 61 feet per second with about 1200 to 2000 g.p.m. of water being introduced into the receptacle through said jet stream nozzles for a slag input rate of about 4 tons per minute; and said water jet streams being injected into the receptacle with a jet velocity of at least about 91 to 145 feet per second with about 3000 to 5000 g.p.m. being introduced through said jet stream nozzles for a slag input rate of 2 to about 4 tons per minute; maintaining water accumulating in said receptacle at a level below the lowermost of said water jet stream nozzles while molten steel slag is being poured into the receptacle; and removing resultant granulated slag particles from said receptacle while the granulation of the molten steel slag is in progress, at an average rate substantially equal to the average rate of molten slag input.

10. A method of handling molten steel slag as defined in claim 9 wherein: the total quantity of water in g.p.m. is supplied according to varying steel slag input rates as stated in claim 9 by means of two flat jet streams, one over the other, with 60% to 75% of said total water g.p.m. input being injected by means of the upper jet stream and 40% to 25% of said total water g.p.m. input being injected by means of the lower jet stream; each jet stream having at least a jet velocity in f.p.s. according to varying steel slag input rates as stated in claim 9.

11. A method of handling molten steel slag from smelting furnace characterized in that it comprises: pouring molten steel slag into a receptacle; injecting at least one flat jet stream of water into said receptacle so as to intercept said molten steel slag to granulate said slag into particles; said water jet stream having a rate of at least 400 g.p.m. per ton of molten slag input per minute with a water jet velocity ranging from at least about 25 f.p.s. for a slag input rate of up to 2 tons per minute to at least about 55–61 f.p.s. for a slag input rate of up to about 8 tons per minute; maintaining the water accumulating in said receptacle at a level below said water jet stream at all times while molten steel slag is being poured into said receptacle so that the molten steel slag intercepts said stream above the water accumulated in said receptacle; and removing resultant granulated slag particles from said receptacle while granulating the molten steel slag in progress, at a rate sufficiently approximating the rate at which molten slag is poured into the receptacle so as to prevent substantial build-up of granulated slag particles within said receptacle.

12. An apparatus for handling molten steel slag from a smelting furnace characterized in that it comprises: slag granulator means including a receptacle; means for pouring molten steel slag into said receptacle; means for injecting a plurality of flat jet streams of water with a trajectory intercepting the path of said molten slag and in sufficient quantity to granulate said steel slag into particles, said means including a plurality of jet nozzles each having a substantially rectangular aperture with a horizontal dimension which is large compared to the vertical dimension thereof, with said jet nozzles disposed one over the other and spaced from each other; means for maintaining water accumulating in said granulator receptacle at a level below the lowermost of said waterjet nozzles while molten steel slag is being poured into the granulator receptacle; and means for moving the granulated slag particles through and agitating the water bath accumulating in said receptacle and for removing granulated slag particles from the receptacle, said means comprising a rake conveyor disposed within said granulator receptacle and including means moving through the receptacle below the level of the water bath accumulating therein and in a direction away from said jet nozzles so as to remove granulated slag particles from the region of interception of said molten slag and water jet streams, said rake conveyor means operating to remove granulated slag at an average rate at least substantially equal to the rate molten steel slag is poured into said slag granulator receptacle.

13. In combination with an open hearth steelmaking furnace in a furnace building having a charging floor in front of the furnace and a kitchen below each charging floor, the furnace having at least one door and spillway opening extending through said charging floor adjacent said furnace door for passage therethrough of molten front flush slag discharged through said door in operation, an apparatus for handling molten slag characterized in that it comprises: a slag granulator including a receptacle disposed in said kitchen and away from below said slag spillway; slag transfer means movable between a first position in which molten slag discharged through said spillway is in a charging floor in operation will pour into said granulator receptacle and a second position in which such molten slag will not pour into said granulator receptacle; said granulator including means for directing at least one jet stream of water to intercept molten slag poured into said receptacle and in sufficient quantity to granulate said slag into particles; means for limiting a water bath accumulating in said receptacle at all times during operation to a level below the region of interception of the molten slag by said water jet stream; and means for removing resultant granulated slag from said granulator receptacle and out of said kitchen while granulating the slag in progress at substantially the rate of molten slag input.

14. An apparatus for handling front flush and tap slag from an open hearth steelmaking furnace located in a furnace building as defined in claim 13, the furnace back wall having a tap hole through which part of the slag is tapped into a steel ladle on said pit side after draining the steel into said ladle, said slag handling apparatus further comprising: means for transferring tap slag from said ladle on said pit side of the furnace to said granulator means in said kitchen and there subjecting the ladle tap slag to a jet stream of cooling medium in sufficient quantity to granulate it into particles, with said granulated slag removal means also removing the resultant granulated tap slag from said granulator means and out of the kitchen and furnace building.

15. An apparatus for handling front flush and tap slag from an open hearth steelmaking furnace located in a furnace building, as defined in claim 13, further comprising: means on the pit side of the furnace for subjecting molten tap slag from said ladle to a jet stream of water supplied in sufficient quantity to granulate the tap slag into particles; and means for transferring the resultant granulated tap slag from the pit side of the furnace while granulation of the tap slag is in progress, and removing it from the furnace building.

16. An apparatus combination as defined in claim 13, wherein said slag transfer means comprises a movable chute having one portion thereof not movably disposed below said spillway opening in the charging floor to receive front flush slag discharged from the furnace and another chute portion extending to the granulator in the kitchen so as
to pour molten front flush slag into said granulator receptacle, means being provided for moving said one chute portion away from below said opening in the charging floor so as to permit the molten slag to fall to below the furnace.

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